

ECOLOGICAL STUDIES ON PELICAN ISLAND, WESTERN PORT, VICTORIA

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Pelican Island is a very small island barely above sea level, 1 km from the east coast of Western Port. It is built up from basaltic cobbles derived from an eroding shore platform. Shallow peat occurs in the centre of the island above what appears to be old salt marsh silt, probably deposited in an embayment during the formation of the island at times of higher sea level in the mid Holocene. The vegetation is unusual since it is dominated by *Acacia melanoxylon* (blackwood) scrub with an understorey of perennial and exotic annual grasses, forbs and succulents. This scrub is rimmed by tussock grasses and the whole island surrounded by a mainly open, rocky salt marsh in the intertidal zone where *Avicennia marina* is represented by two small, isolated bushes and several seedlings. The blackwood scrub is pruned by salt-laden winds and is continuously attacked by wood boring larvae. It recovers vegetatively and regenerates only by root suckers.

Flowers are usually aborted and therefore seed production is extremely rare under these conditions. No blackwood seedlings have been germinated from the soil seed bank which consists predominantly of *Tetragonia tetragonioides*. From isozyme analysis of blackwood phyllodes it seems that the north and south of the island are occupied separately by two main genotypes which have regenerated clonally. It is hypothesised that two seeds were dispersed to different parts of the island, probably by birds, when sea levels fell and the site became habitable to dry land plant species. The blackwood scrub is probably vulnerable because of possible sea level rise, the persistent insect attack, the low genetic variability and the possibility of invasion by other woody species that may be better adapted and more competitive.

Key words: blackwood scrub, cobbles, peat, salt wind.

PELICAN Island is one of the few islands in Western Port to have escaped the clearing and grazing activity of last century, hence a study of its ecology and history was deemed appropriate for the last research undertaking of the McCoy Society for Field Investigation and Research—a multi-disciplinary society inaugurated at Melbourne University in 1935. Pelican Island is a low, scrub-covered island rimmed by tussock grass and rocky salt marsh 900 m west of Corinella. From general observations in Victoria it was expected that it would be dominated by *Allocasuarina verticillata*, *Myoporum insulare* or *Melaleuca ericifolia*, therefore the presence of 0.30 ha of stunted, wind-pruned blackwood scrub required some explanation. Local knowledge speaks of 'guano' mining 70–80 years ago, which added further interest to the problem of the formation of the island and the reasons for its peculiar vegetation.

This paper will be presented under the three headings of: General Environment and History, Vegetation, and Status of the *Acacia melanoxylon** population.

GENERAL ENVIRONMENT

Geology

Pelican Island (lat. 38°24'S, long. 145°24'E) is the summit of a flat hilltop rising from the floor of the east channel of Western Port. It consists of Oligocene Basalt (Thorpdale Volcanics) and is close to the northern limits of the deep Flinders flow (Spencer Jones et al. 1975). One of the many faults or monoclines that dissect the Western Port basin passes very close to Pelican Island, and the riffle line in the sea which extends some way towards Corinella may represent a marked change of sea floor level at this point. Evidence of an early Holocene sea level 1 m above that at the present time has been demonstrated at Corinella and Philip Island (Marsden & Mallett 1975; Jenkin 1988), however, as pointed out by Bird (1981, 1994) local tectonic uplift could have produced a similar result. Certainly Pelican Island is very close to the edge of the upthrown block of the Corinella fault (Jenkin 1962).

*Nomenclature of vascular plants follows that provided by Ross (1996).



Fig. 1. Photograph of Pelican Island from the west.

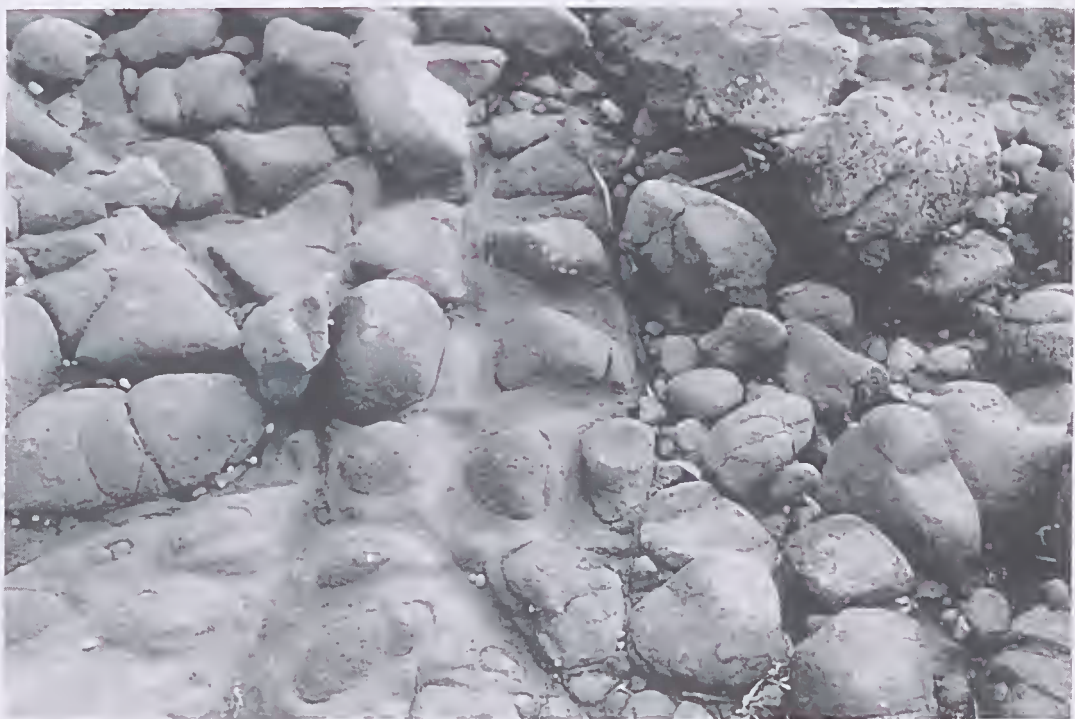


Fig. 2. Core stones in basalt columns on the rock platform.



Fig. 3. Veneer of cobbles on the southern shore platform.



Fig. 4. Berm of cobbles deposited at high tide on the southern coast, *Lavatera arborea* in the foreground in dense swards of *Poa poliformis* and dead *Acacia melanoxylon* in the background.

Physiography

The island is narrowly triangular, 180 m long and 55 m wide, aligned NE-SW and encompassing an area of 0.42 ha, the highest point of which is only 2.1 m above the spring high tide mark (Fig. 1). At low tide a broad shore platform 20–50 m wide slopes at about 3° on the northwestern side and about 2° on the southeastern side of the island. The northeastern tip is prolonged into a trailing spit of sand and shell fragments which has shown considerable truncation since 1956. An old wave-cut clifflet 1 m high which extends down much of the NW side of the island is partially obscured by detritus of clayey grit but in the north the basalt bedrock and a thin palaeosol of gritty sandy clay is exposed beneath a layer of basalt cobbles. Such marine erosion probably took place when sea levels were higher and has ceased since tussocks of *Austrostipa stipoides* and *Isolepis nodosus* have

established to seaward. The rock platform in this area is covered intermittently with a single layer of basalt cobbles (Fig. 2) derived from the core stones of truncated, hexagonal basalt columns (Fig. 3). Down the western side of the island smaller core stones are being deposited to depths of 20–30 cm near the high tide level amongst open stands of *Suaeda australis*. At the exposed southwest of the island such core stones have been thrown up as a conspicuous rampart or ridge 50–60 cm high in front of the *Austrostipa-Poa* grass zone (Fig. 4). The area of the island above high tide is increasing since this material continues to be deposited from the shore platform. On the eastern side, large sheets of basaltic sand and shell fragments occur amongst the stones and the basalt bedrock and silty mud only occurs on the summits of rocks or on the platform surface close to the low tide mark. The extent of silty clay however varies with the frequency of severe storms and

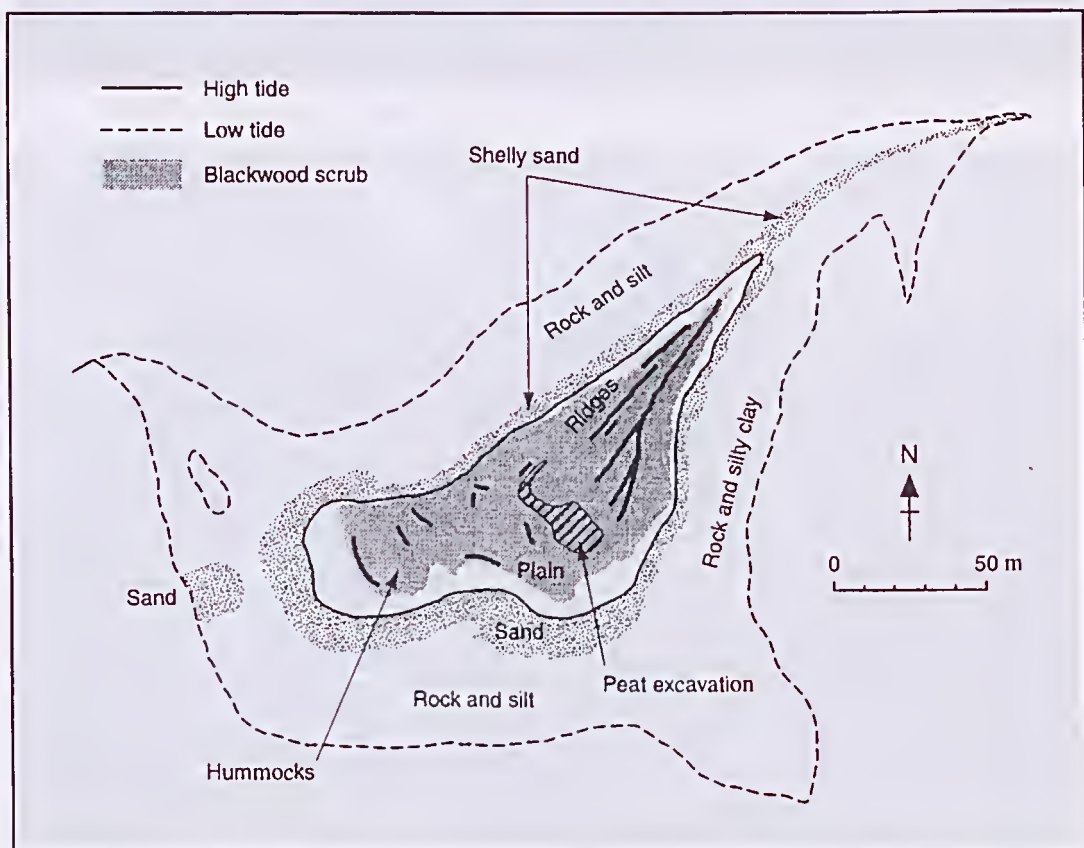


Fig. 5. Physiography of the island showing ridges and hummocks of cobbles and the areas of peat.

was much less prevalent in 1998 than five years previously. The occurrence of shells of the relatively rare Holocene brachiopod, *Magellania flavesceus* Lamarck, near the high tide mark is of interest. The surface of the island is largely composed of heaped cobbles similar in size to those on the present shore platform. Deeper and possibly older deposits occur towards the interior of the island. In the NE half of the island cobbles are distributed in subparallel ridges 1.0 m high, whereas in the SW section the cobbles occur either in a flat plain or in a complex of small peaks and hollows as if two parallel systems have interacted to produce a diffraction pattern of hummocks and hollows (Fig. 5). In the centre of the island at its widest point, a level plain with surface peat is bisected by a man-made small trench which abruptly turns SE into a rectangular excavation 5×8 m and 1 m deep before leading out towards the coast. Evidence of these workings can be seen clearly from the aerial photographs of 1956 where a recent fire had removed all surface vegetation. In this region local deposits of pale silt 15–25 cm thick, occur at depths of 60–120 cm. This material which was examined by Laola Pty Ltd, Perth, Western Australia, revealed chenopodiaceous pollen. This material is remarkably similar to that in present day salt marshes and may represent old salt marsh deposits in the early phase of the island's development.

Climate

The climate is temperate with a seasonally well distributed annual rainfall of 800 mm (Shapiro 1975). Prevailing winds are NW to W in winter and W to SE in summer. The fetch of winds across Western Port to Pelican Island varies from 2.5 to 13.8 km and is greatest from SSW to S (Fig. 6; Shapiro 1975; Commonwealth Meteorological Bureau). The winds causing most salt aerosol damage to the scrub are likely to be W–SW in winter and SW to SE in summer. The on-shore winds of spring and early summer are likely to be the most damaging due to the presence of new shoot growth.

Soil

Soils on the island are immature with little profile differentiation and their development is closely linked to topography and substrate (Fig. 7). The major soil type is a stony humus loam developed from accumulations of cobbles, somewhat similar to the skeletal soil on the early Holocene cinder cone of Mt Eccles in western Victoria (Gibbons

& Downes 1964). Around the periphery of the island shelly, basaltic sand has accumulated and is frequently mixed with variable amounts of undifferentiated marine detritus, especially that of *Zostera muelleri* and macroalgae, which on the east coast extends inland for 1–5 m. These sediments may also be interspersed to various extents with basaltic cobbles. On the central flat areas of the island an undifferentiated humus horizon grades into or is embedded in a layer of cobbles at 20–50 cm. In some places granular peat 20–30 cm deep occurs over a compacted fawn layer at least 30 cm deep of silt, sandy silt or silty clay. From levelling surveys and soil pits the basalt basement on the island occurs at a depth of at least 1 m. In the salt marsh areas along the east coast, substrate ranges from shelly sand to silty clay and soil profile development is meagre. The granular humus-rich horizons (0–15 cm) in the centre of the island, have pH values close to neutrality (6.5–7.3) and are high in 'available' phosphorus and total nitrogen. The C:N ratio is 10.8–12.3 which suggests that nitrogen would be readily available to plants (Table 1).

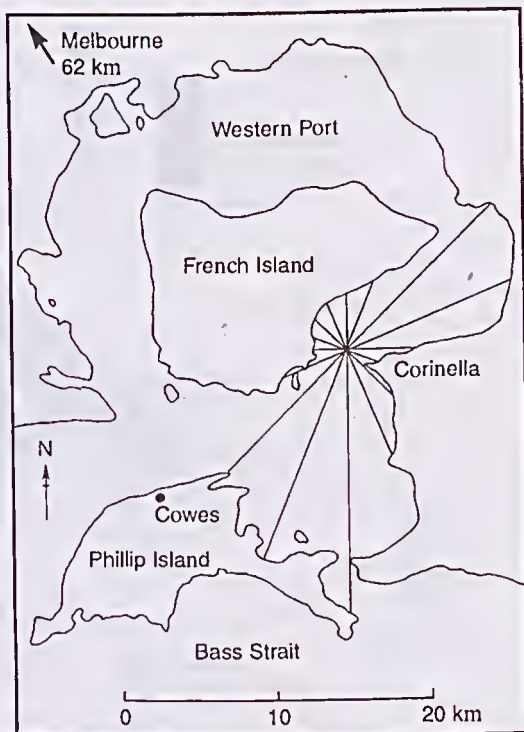


Fig. 6. Pelican Island showing the fetch of winds from various compass directions.

	Pit 1	Pit 2
pH (1:5 dilution)	7.3	6.5
P (ppm)	390	210
N (%)	1.69	2.15
Organic matter (%)	31.4	45.4
C:N	10.8	12.3

Table 1. Nutrient analysis (oven dry weight) of peat samples (0–15 cm), Pelican Island.

History

The earliest records of land use can be traced to exploitation of the rich humus developed on the island in the blackwood scrub. In 1918 a licence was taken out for extraction of 'guano' for

agricultural purposes—mainly for use as fertiliser for the vegetable garden of the prison farm at McLeod on French Island (Allan Chandler, pers. comm.). A small hut present on the island for many years was probably associated with the remains of a small excavation and trench observed today. Work on this venture ceased in 1928. Since that time the island has been visited by fishers and others. Fires have occurred at various times—the effects of one which burnt out 60% of the blackwood scrub (Fig. 8) and revealed workings of the superficial peat harvesting has been recorded on the 1956 aerial photographs.

Discussion

The process of core stone weathering on the shore platform is continuing today and in places

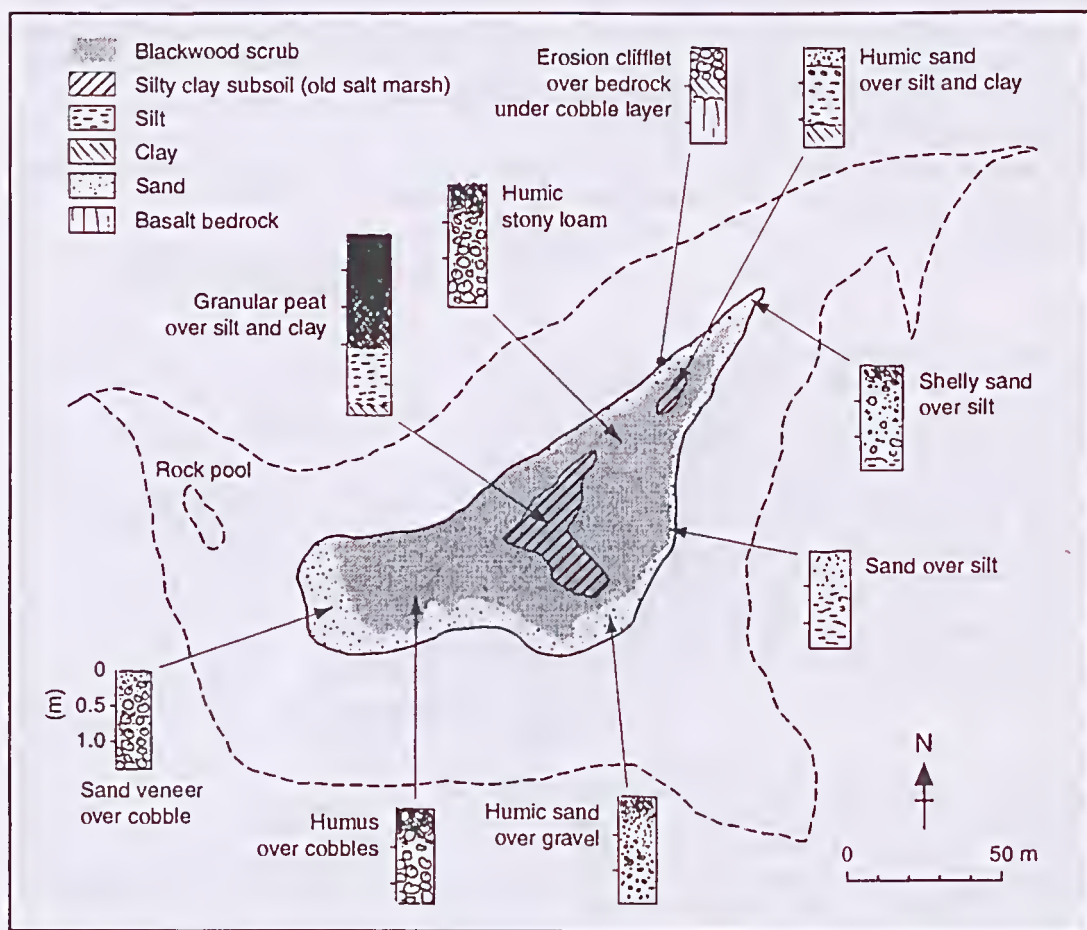


Fig. 7. Map of main soil types on Pelican Island.

cobbles are being accumulated as a continuous veneer. Storms, tidal scour and currents have caused considerable changes in the superficial deposits of fine material. The prevailing winds are NW and SW, although winds from the E and SE may be severe and prolonged. The island has been subjected to some erosion from wave action as well as sand deposition at high tide on the NW side and to sand and fine sediment accumulation on the SE. Under the present climate it is difficult to see how storms could generate wave energy sufficient to

lift cobbles 1.5 m and distribute them into ridges parallel with the NW coast. However, this would seem feasible if sea levels had been 1 m higher, as suggested by Marsden & Mallett (1975) and Jenkin (1988) for various sites around Western Port. The main accumulation of cobbles could have occurred at this time when Pelican Island would have been little above high tide level. The chaotic pattern of hummocks and hollows of cobble deposit in the SW end of the island would be consistent with an interacting system of cobble ridges being

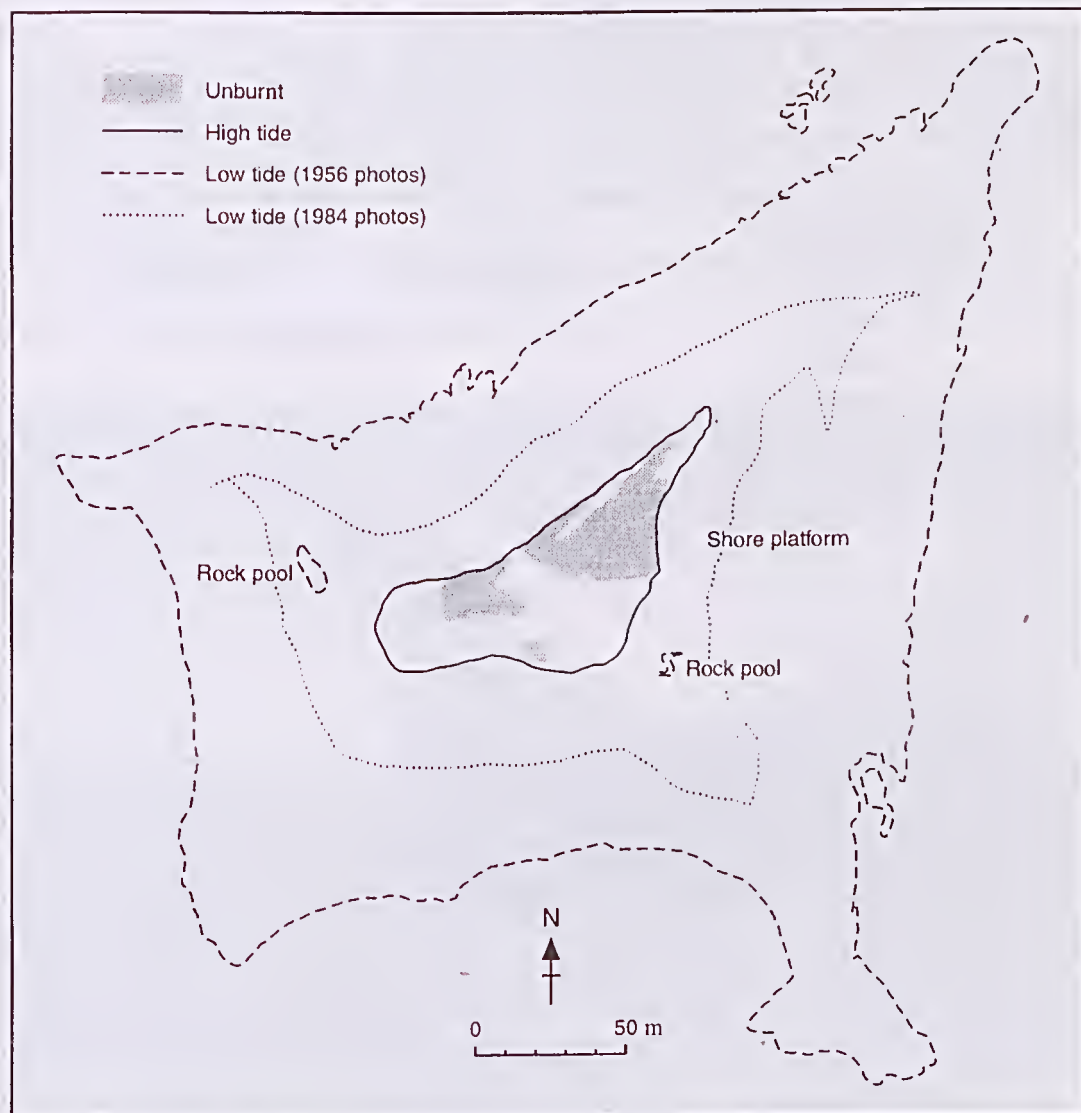


Fig. 8. The extent of the 1956 fire.

assembled from NW and SW storm-driven wave systems. The silt deposits in parts of the island at depths of 50–100 cm are likely to be old salt marsh muds deposited at higher relative sea levels during the build-up phase of the cobble ridges. Pollen analyses of the silts suggests their salt marsh origin due to a large component of chenopodiaceous species. Much of the thick humus material in the centre of the island may have originated at this time from extensive deposits of sea grass detritus in embayments in the cobble ridges. Much of the high nutrient status of the material could have been associated with sea bird roosts at a time when the island is likely to have been grassy marsh land at a time of higher sea level. Today sea bird droppings are most prevalent on the sand spit and in the bare zone close to the limit of the highest high tides. Deep accumulations of sea grass and macro-algal debris occur around the shores of Western Port today and can be observed on the marshes at the mouth of the Bass River and at Shorcham.

Leaves of sea grasses are known to be high in P (0.19% ODW) and N (1.64% ODW) from the work of Clough & Attiwill in Shapiro (1975). Extensive beds of such grasses exist today within 100–200 m of Pelican Island to the south, south-west and east-north-east (Marsden in Shapiro 1975). The humic top soil under blackwood scrub has been enriched considerably by humus derived from the litter and fine roots of the present vegetation.

VEGETATION

Vegetation structure

The dry-land vegetation of Pelican Island is essentially a low scrub of *Acacia melanoxylon* with a dense understorey of grasses and the scrambling succulent, *Tetragonia tetragonioides*. This is surrounded by a zone of tussock grasses (*Austrostipa stipoides* and *Poa poiformis*) with admixtures of

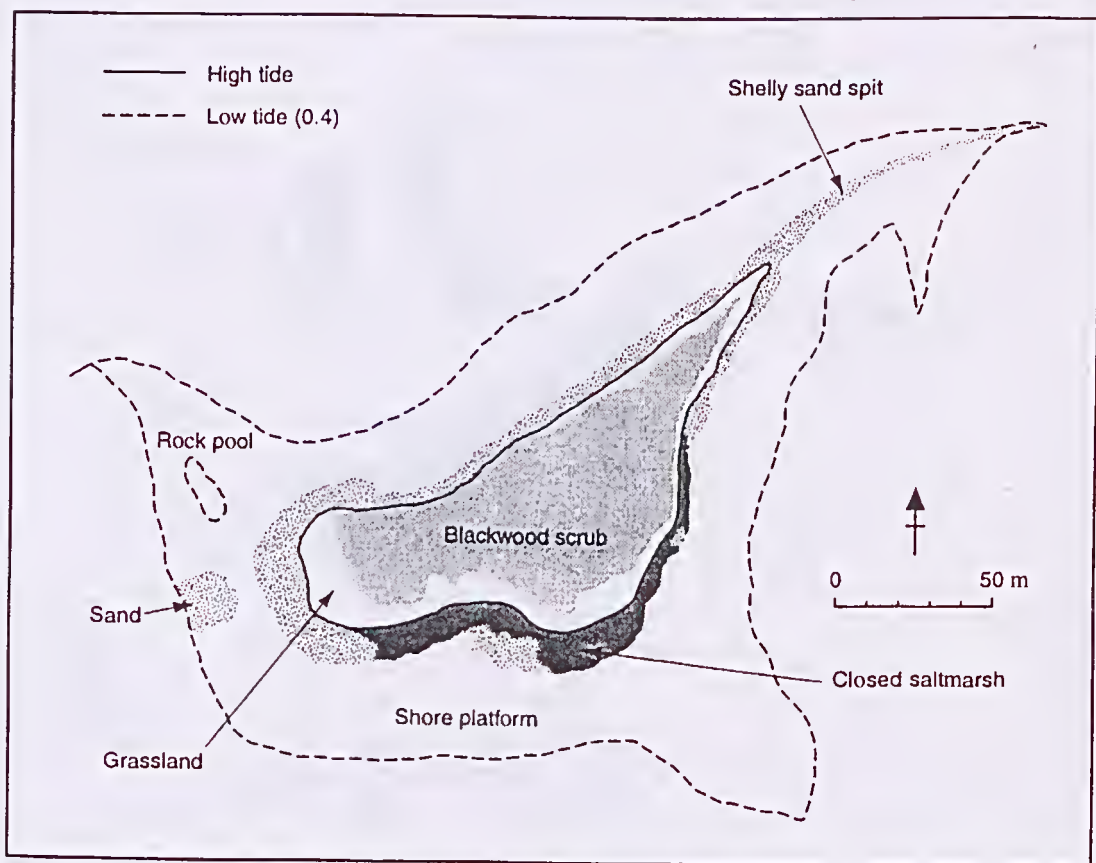


Fig. 9. Distribution of the main structural forms of vegetation.

low chenopodiaceous shrubs. On the shore platform, salt marsh is variably developed between neap and spring high tide levels. The distribution of the major structural formations is shown in Fig. 9 and a vegetation profile bisect across the island at its widest point is shown in Fig. 10

In much of the open scrub in the western half of the island the introduced shrub *Lavatera arborea* codominates, but in the southern area, blackwood

increases in density and shows marked salt-wind pruning from prevailing southerly winds (Fig. 11). *Clematis microphylla* climbs over and binds together many shrubs in the centre and south of the island (Fig. 12). Degenerate and dead shrubs of *Acacia* and *Lavatera* are widespread (Fig. 13). The other wiry liane, *Muehlenbeckia adpressa*, is locally common and tends to occur on the northern areas. *Tetragonia tetragonioides* is festooned over

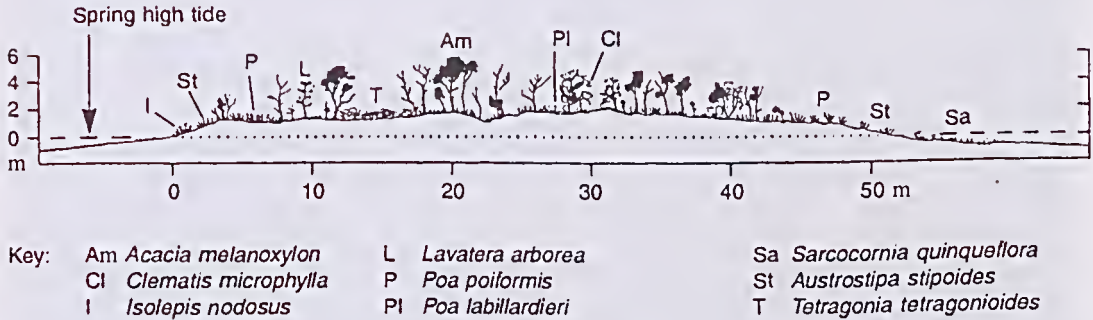


Fig. 10. Vegetation profile across the widest part of the island.



Fig. 11. Wind pruned profile of *Acacia melanoxylon* scrub on the south coast.



Fig. 12. Scrub of *Acacia melanoxylon* and *Clematis microphylla* with lush introduced grasses.



Fig. 13. Degenerate *Acacia melanoxylon* scrub with *Poa labillardierei* and *Tetragonia tetragonioides* in the centre of the island.

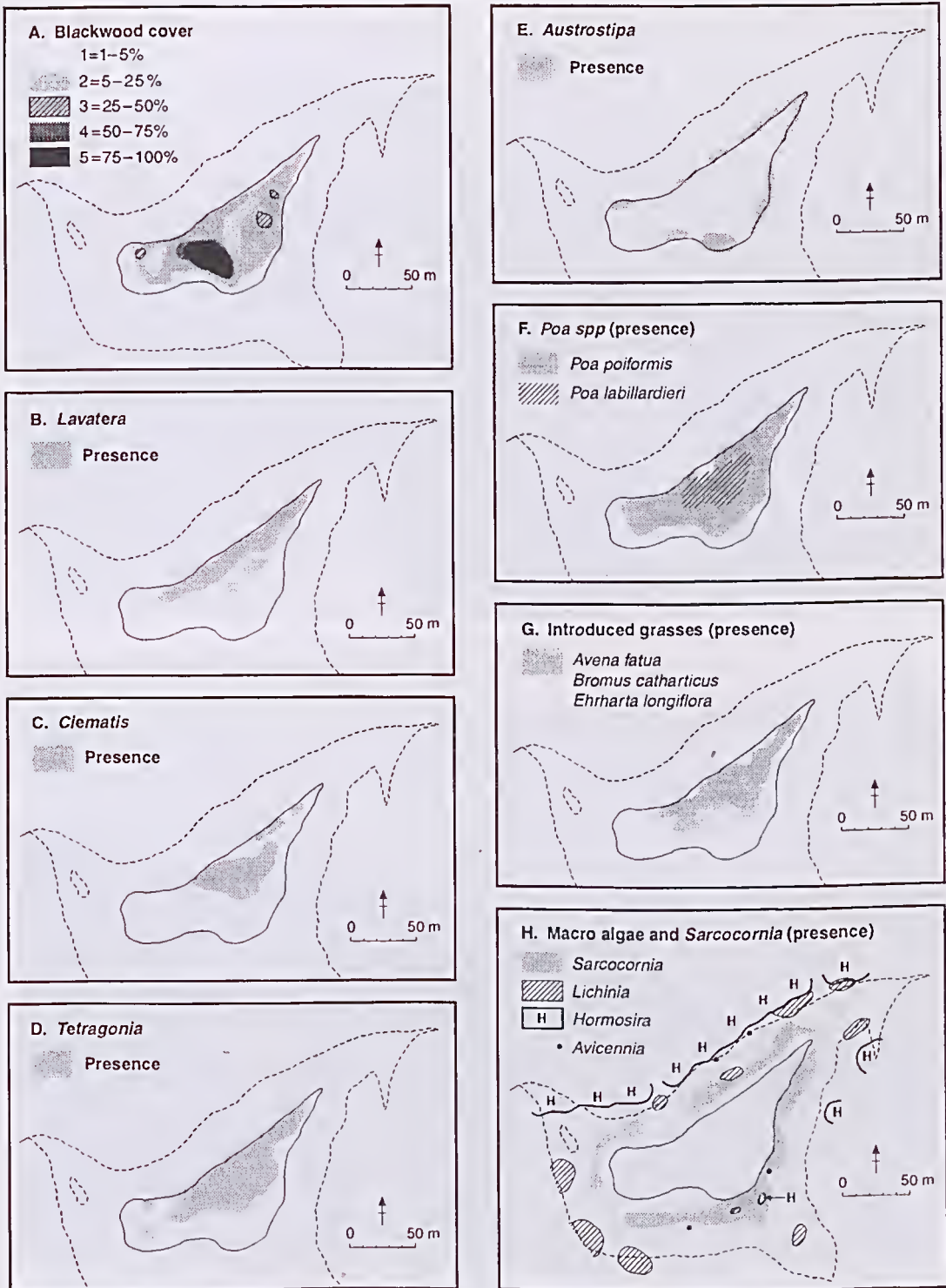


Fig. 14. A-H, Distribution maps of the major species.

shrubs or developed as lush carpets amid swards of perennial native tussock grasses (*Poa labillardierei* and *P. poiiformis*) or vigorous, annual introduced grasses (*Ehrharta longiflora*, *Bromus diandrus* and *Avena sterilis*). The weedy areas of the island are in the centre and north and members of the Asteraceae are prominent (*Carduus tenuiflorus*, *Sonchus oleraceus* and *Conyza canadensis*). Low-growing native and introduced herbs (eg. *Stellaria media*) occur where competition from the understorey is less, such as under the deeper shade of denser blackwood. The distributions of major species are shown in Fig. 14A–H.

At the periphery of the scrub, native tussock grasses are often associated with *Dianella revoluta* and *Enchylaena tomentosa*. On the exposed north-east edge, open ground has allowed the development of weedy masses of *Oxalis pes-caprae* and other species. In this zone, the only four moss species on the island (*Bryum campylopus*, *Tortula princeps*, *Rhynchostegium tenuifolium* and *Racomitrium convolutaceum*) occur at the bases of grass tussocks.

On the exposed NW side of the island the

cobble-strewn shore platform is colonised by widely scattered *Sarcocornia quinqueflora*. This gives way to a zone of open *Suaeda australis* in front of *Austrostipa stipoides* grassland (Fig. 15). On the sheltered SE the marsh community is better developed on shelly sand and silts and may be continuous (Fig. 16) or occur as a mosaic of succulents and cobble patches (Fig. 17). The closed marsh varies from *Sarcocornia quinqueflora*–*Suaeda australis* swards with local areas of *Samolus repens* and *Hemichroa pentandra*, to shrub patches of *Enchylaena tomentosa* and occasional *Sclerostegia arbuscula*. Two small bushes of mangrove (*Avicennia marina*) occur on the SE coast—one occurs in the seaward part of the salt-marsh and the other, near the mean tide mark in crevices in rock surrounded by cobbles (Fig. 18). Occasional seedlings (< 50 cm tall) and germinated seed occur at several places around the island. At the spring high tide level a debris-line occurs in the grassland between the zones of *Austrostipa stipoides* and *Poa poiiformis* (Fig. 19) where conspicuous shrubs of *Atriplex cinerea* may also be present.



Fig. 15. Zonation on the exposed NW coast from cobble-strewn shore platform with widely scattered succulents to open salt marsh of *Suaeda australis* and *Enchylaena tomentosa* in front of the *Austrostipa stipoides* grass zone.



Fig. 16. Zonation on the sheltered SE coast from grassland fringe to closed salt marsh (*Sarcocornia quinqueflora*) and open rocky salt marsh. Corinella bluffs can be seen in background.



Fig. 17. Mosaic of salt marsh, mainly *Suaeda australis*, and cobbles on the east coast.



Fig. 18. Solitary mangrove (*Avicennia marina*) bush, 1.5 m high, on the rocky shore platform of the SE coast.

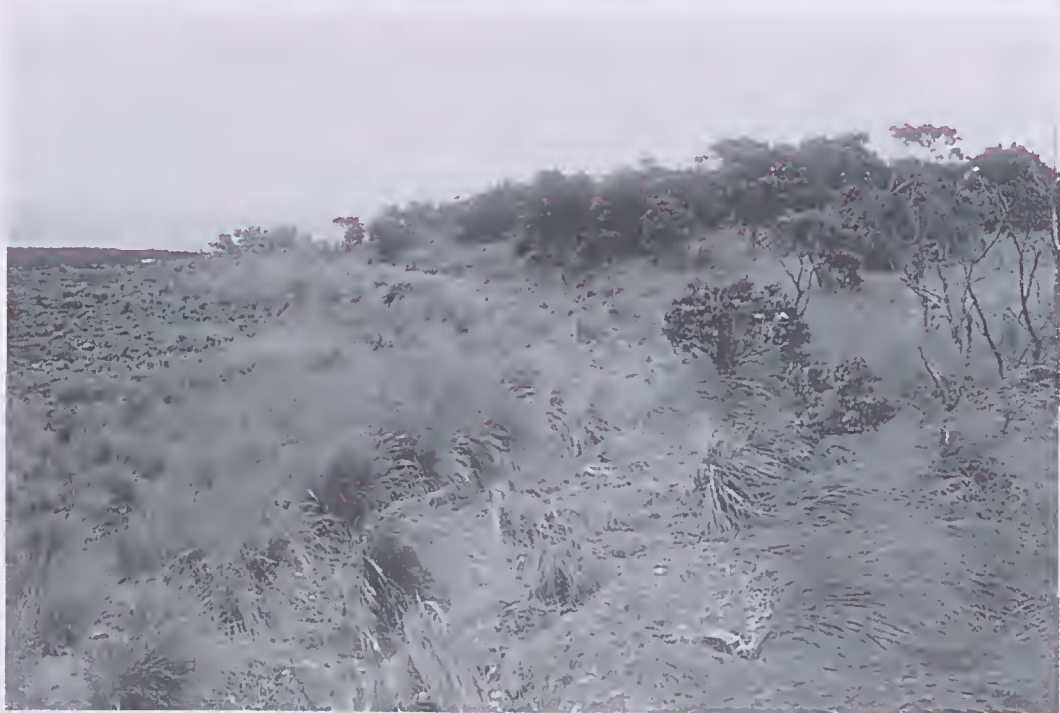


Fig. 19. Spring high-tide debris line discriminating between *Austrostipa stipoides* and *Poa poiformis* in the grassland on the E coast.

Landward of the zone of halophytes, a zone of rock and shelly sand are generally devoid of vegetation for 5–10 m, except for the orange lichen (*Caloplaca marina*) on the summits of boulders, above high tide. The darker lichen (*Licinia confinis*) occurs over much of the intertidal zone and extends to the extreme landward limits of marine inundation. The first macroalga appearing with increasing frequency of tidal inundation is *Enteromorpha intestinalis*, but at distances of 30–40 m from the high tide limit, turfs of *Hormosira banksii* and *Ulva lactuca* become common. On the sheltered side of the island, *Zostera muelleri* forms low swards in small sheets of sand. One large rock pool 8–10 m wide in the SW end of the rock platform, contains communities of a red alga (*Hypnea muciformis*), and the brown alga, *Cystoseira trinodeus*—a new Victorian record (G. Kraft, pers. comm.).

The vascular species found on the island are listed in the Appendix.

Objective methods of floristic analysis

Methods. Species were recorded in 122 quadrats (4×1 m) aligned at right angles to the long axis of the island and located at the intersections of a 10 m grid. Each species in each quadrat was assigned a cover class (+–5) on the Braun Blanquet scale (+, present; 1, cover 1–5%; 2, cover 5–25%; 3, cover 25–50%; 4, cover 50–75%; 5, cover 75–100%). The species composition of the quadrats was sorted by the agglomerative TAXON program, MACINF (Ross 1982) and expressed as percentage frequency of occurrence in each grouping.

Results. The hierarchical classification was truncated at the 12 group level and examination of their distribution and composition indicated 11 groups could be readily interpreted. The zonation of the groupings of vascular species around the island is shown in Fig. 20. Most of the community diversity occurs in the general interface between grassland and salt marsh.

Scrub GROUP A is scrub of *Acacia melanoxylon* and subdominant *Lavatera arborea* with dense *Tetragonia tetragonioides*, *Clematis microphylla* and lush grass swards of *Poa poiformis* and *P. labillardierei* as well as the exotic annual grass species (*Bromus sterilis*, *Ehrharta longiflora*, *Avena sterilis* and *Holcus lanatus*) and the spear thistle, *Carduus tenuiflorus*.

GROUP B is an open scrub of *A. melanoxylon* and *L. arborea* with *Tetragonia tetragonioides*, *Dianella revoluta*, *Acaena novae-zelandiae* and an

admixture of succulents in a dense grass sward of *Austrostipa stipoides* and *Poa poiformis*.

Peripheral grassland GROUP C is tussock grassland with scattered *Lavatera arborea*. The chief grasses are *Poa poiformis*, *Distichlis distichophylla* and *Austrostipa stipoides*, with the sedge, *Isolepis nodosus*, and the lily, *Dianella revoluta*. Several semi-succulents, such as *Apium prostratum*, are present.

GROUP D is a halophyte grassland of *Austrostipa stipoides* associated with a lesser stratum of *Sarcocornia quinqueflora*, *Suaeda australis*, *Disphyma crassifolium* and *Apium prostratum*.

GROUP E is a short tussock grassland dominated by *Poa poiformis* with *Distichlis distichophylla*, *Senecio lautus* and *Dianella revoluta* and occasional *Lavatera arborea*.

GROUP F is an open grassland sward consisting of *Austrostipa stipoides*, *Suaeda australis* and *Disphyma crassifolium*.

Halophyte marsh GROUP G is a halophyte community at the landward side of the marsh with admixtures of *Disphyma crassifolium*, *Apium prostratum*, *Suaeda australis* and *Sarcocornia quinqueflora*.

GROUP H is closed salt marsh turf comprising *Sarcocornia quinqueflora* and *Suaeda australis* with lesser contributions from *Samolus repens*, *Hemichroa pentandra* and *Sclerostegia arbuscula*.

GROUP I is an open rocky halophyte community comprising *Suaeda australis* and/or *Sarcocornia quinqueflora*.

Mangrove GROUP J. This monospecific group consists only of isolated shrubs and seedlings of *Avicennia marina* on the rocky weathered shore platform.

The species composition of these 10 groups is shown in Table 2.

Floristics

The vascular flora of the island consists of 81 species of which 53% are exotic. Grasses are conspicuous, 47% of which are exotic. Of 11 composites present, 90% are exotic, whereas only one of the nine chenopods is exotic (Appendix). The flora is generally consistent with that found in other maritime locations in southern Victoria (Barson & Calder 1981). However, the curious feature of the island is the scrub dominated by *A. melanoxylon*. In Western Port this species is found near sea level on the sheltered coast of French Island, but on the exposed mainland coast at Corinella it occurs at least 100 m inland.

Species	*A(43) Scrub	Scrub B(12) Open scrub	C(13) Open grassy scrub	Grassland D(7) Tussock grass- land	E(4) Short grass- land	F(15) Salt marsh landward	Salt marsh G(39) Complex salt marsh	H(3) Rocky open marsh	Mangal I(1) Mangrove
Shrubs									
<i>Acacia melanoxylon</i>	100	25							
<i>Lavatera arborea</i>	49	42	41						
<i>Myoporum insulare</i>							3		
<i>Avicennia marina</i>									+
Herbs									
Graminoids									
<i>Dianella revoluta</i>	19	75	77						
<i>Isolepis nodosus</i>		25	77						
<i>Juncus kraussii</i>			15	12					
<i>J. pallidus</i>		17							
* <i>Gladiolus</i> sp.	2								
<i>Austrastipa stipoides</i>		50	31	100	10	18			
<i>Poa poiformis</i>	72	50	92						
<i>P. labillardierei</i>	33								
<i>Distichlis distichophylla</i>	9	17	77	25	100		5		
<i>Spinifex hirsutus</i>							25		
* <i>Bromus diandrus</i>	16								
* <i>Avena sterilis</i>	32								
* <i>Ehrharta longiflora</i>	30								
* <i>Briza maxima</i>	12								
<i>Danthonia racemosa</i>	2								
* <i>Thinopyrum junceiforme</i>	9	17							
* <i>Parapholis strigosa</i>	2						2		
<i>Holcus lanatus</i>	5								
Forbs (dicots)									
<i>Tetragonia tetragonioides</i>	86	58	15				8		
* <i>Atriplex prostrata</i>		67	8						
<i>Chenopodium glaucum</i>		8							
<i>Clematis microphylla</i>	49								
<i>Muehlenbeckia adpressa</i>	21	8							
<i>Dichondra repens</i>	19	8	15						
<i>Geranium solanderi</i>	32		15						
<i>Pelargonium australe</i>	5		15						
<i>Senecio lanius</i>	2	3	46						
<i>Rumex brownii</i>			7						
* <i>Rumex crispus</i>		33	2						
* <i>Anagallis arvensis</i>	2								
* <i>Aster subulatus</i>			23						
* <i>Hypochoeris radicata</i>	2		46						
* <i>Conyza albida</i>	7								
* <i>Carduus pycnocephalus</i>	16								
* <i>Sonchus oleraceus</i>	19	67							
* <i>Galium aparine</i>	2								
<i>Acaena novae-zelandiae</i>	5								
<i>Rubus parvifolius</i>	21								
* <i>Polycarpon tetraphyllum</i>			7						
* <i>Medicago polymorpha</i>			7						
* <i>Verbascum virgatum</i>			5						
<i>Samolus repens</i>							10		
<i>Hemichloa pentandra</i>							8		
<i>Atriplex cinerea</i>							3		
<i>Sarcocornia quinqueflora</i>		8		75	10		100		
<i>Suaeda australis</i>		25	15	87	15	73	49	100	
<i>Sclerostegia arbuscula</i>							13		
<i>Apium prostratum</i>		8	30	62		47			
<i>Disphyna crassifolium</i>	9	25	15	87		47			

Table 2. Percentage frequency of major species in objectively classified quadrat groups. *exotic species; No. of quadrats in brackets; + one record in a monospecific group.

Soil seed bank estimates in the blackwood scrub

This was an attempt to assess the presence of latent species on the site not expressed in the present vegetation. It was assumed that any blackwood seed would have accumulated in the soil due to its hard-seededness.

Methods. Two assessments were made from samples collected from areas 15×15 cm to a depth of 5 cm. In the first case, 5 sites were randomly chosen in January 1992, in the northern half of the island, soils were coarse-sieved and placed in 20×30 cm trays in the glasshouse. Seedlings were removed as they were identified at intervals of 1–3 weeks over 9 months. When the rate of germination had diminished after 4 months, soils were heated by the addition of 1 litre of hot water (95°C) per tray and then cultivated.

In the second trial, three samples were collected from each of three zones: the northern, middle and southern third of the island in May 1993. Treatments were similar with the exception that all trays were placed outside in sunny positions where temperature variation would be considerable. The results of all counts were expressed as numbers per m². In the second trial known numbers of *A. melanoxylon* seeds were buried at marked places in the trays. Several control trays of sterilised sand were also placed amongst the test soils to check for migratory seeds.

Results. The results were surprising in two respects. No *A. melanoxylon* seedlings appeared in any tray, except where seeds had been deliberately planted. By far the greatest concentration of soil seed was derived from the germination

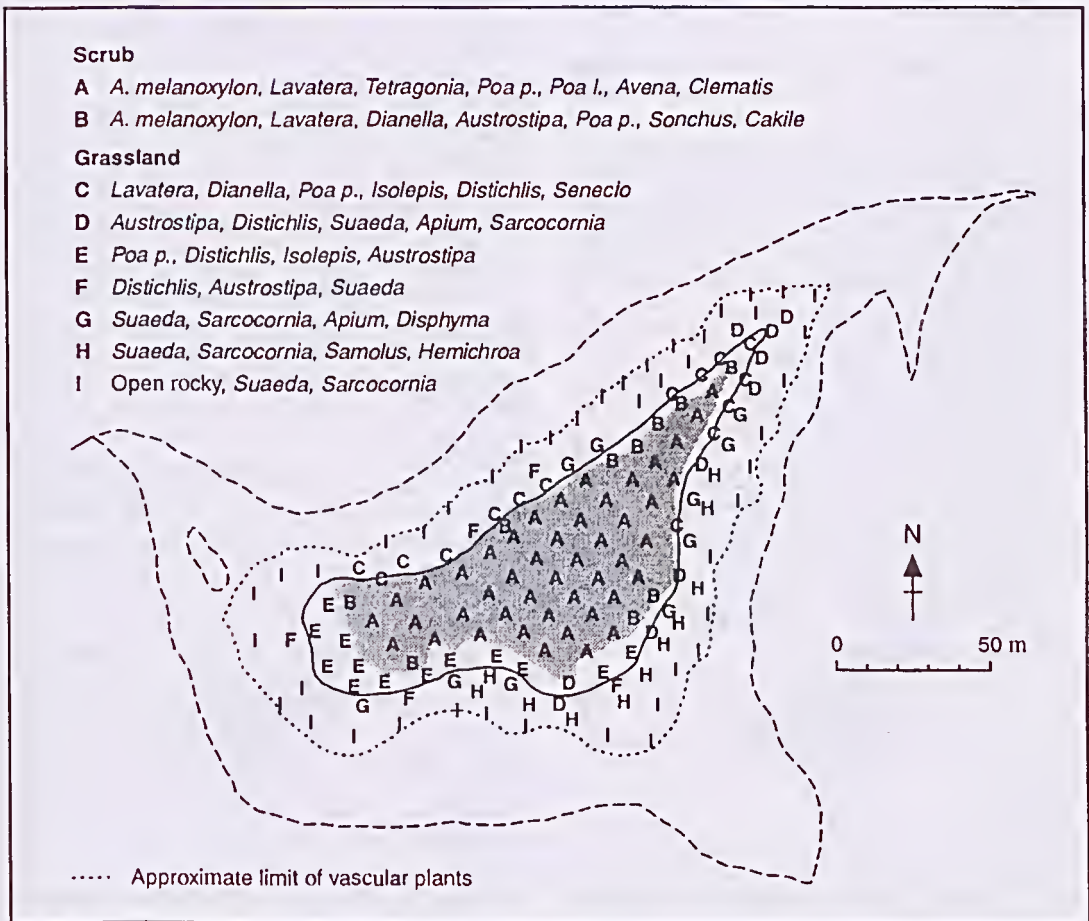


Fig. 20. Distribution of objectively determined species groupings.

of *Tetragonia tetragonioides* which comprised 78.5% of the seed bank. The mean density of this species to a depth of 5 cm was extremely high ($30\,529 \pm 1419\text{ m}^{-2}$), of which 84% arose from buried woody capsules. The number of species recorded from the seed bank trials was 38, of which 26 were exotic. Eleven species had not been recorded in the current vegetation and 53 species present in the vegetation were not recorded in these assessments of the seed bank. A summary of the soil seed bank densities is given in Table 3.

	No. m ⁻²
<hr/>	
Shrubs and vines	
<i>Acacia melanoxylon</i>	0
* <i>Lavatera arborea</i>	193
<i>Clematis microphylla</i>	31
Herbs	
Graminoids	
<i>Poa poiformis</i>	1070
* <i>Ehrharia longiflora</i>	2069
* <i>Bromus diandrus</i>	2493
* <i>Avena sterilis</i>	60
<i>Juncus pallidus</i>	42
<i>Dichelachne crinita</i>	2
Forbs (dicot)	
<i>Tetragonia tetragonioides</i>	30 529 \pm se 1314
* <i>Stellaria media</i>	1227
<i>Geranium solanderi</i>	228
<i>Pelargonium australe</i>	20
* <i>Verbascum virgatum</i>	73
* <i>Trifolium glomeratum</i>	75
* <i>Galium aparine</i>	35
<i>Oxalis corniculatus</i>	104
* <i>Carduus pycnocephalus</i>	81
* <i>Hypochoeris radicata</i>	7
* <i>Trifolium dubium</i>	13
* <i>Crepis capillaris</i>	34
<i>Senecio laetus</i>	35
* <i>Rhaphanus raphanistrum</i>	13
* <i>Sisymbrium officinale</i>	25
* <i>Modiolus carolinianus</i>	13
* <i>Cerastium glomeratum</i>	7
* <i>Veronica arvensis</i>	13
* <i>Lythrum hyssopifolium</i>	7
Total	39 187
<hr/>	
% germinates of total; minus <i>Tetragonia</i>	
Shrubs	0.6
Graminoides	14.6
Forbs	84.8
Exotics	18.0
	81.7

Table 3. Density of soil seed bank germination, May 1992–February 1993. $n = 20$ sites over whole island; area = 225 cm^2 ; depth = 5 cm; * = exotic species.

Discussion

The zonation of the communities around the island is consistent with the response to exposure to salt-laden wind and tidal influences. The vegetation of the island prior to the 19th Century was probably a scrub with a dense understorey of perennial tussock grass, scramblers and herbs. The dominance of grass and lack of sclerophyll species under such conditions suggests a response to soil fertility (Specht 1972). The abundance of ruderal species suggests a history of disturbance. The blackwood scrub is relatively uniform, although subcommunities can be recognised, especially at the margins where, in response to less competition but more exposure, *Dianella revoluta*, *Senecio laetus* and *Geranium solanderi* may be conspicuous. *Tetragonia tetragonioides*, together with many weedy grasses and herbs, is common in the sparser areas of scrub.

The conspicuous peripheral grass zone is probably a result of the tolerance of those species to aerial salt and wave splash as well as the freedom from competition of overstorey shrubs. The admixture of halophytes in the peripheral zone increases as the limit of high tides is approached. The zone immediately below this is often environmentally severe and growth is usually sparse. The rocky salt marsh is an unusual feature of the island and may be related to the balance of deposition and removal of sediment between the cobbles and the polygonal joints in the basalt. As expected, more sediment occurs on the sheltered eastern side of the island where the salt marsh tends to form closed communities particularly toward the limits of the neap high tides. On the exposed western side of the island the communities are very open. Zonation of species on the weathering shore platform is almost certainly due to both surface temperature and salinity fluctuations related to the balance of inundation and exposure over the 2 m tidal range. Continuous turfs of the brown alga, *Hormosira banksii*, only develop well below the neap low tide level. Mangrove plants are rare and occur on a sparse veneer of cobbles and sediment at the level of neap low tide. However, the presence of three recently established seedlings 30–40 cm high, as well as numerous germinated seed, suggests that this community may eventually develop further as has happened on basalt at Williamstown in Port Phillip Bay. Why it has not developed previously on Pelican Island is not known.

The large complement of exotic species is likely to have been the result of human interference in sites of high fertility. Major species include annual

and perennial grasses and composites which are predominant especially where the blackwood overstorey is more open and senescent. The weed species are well represented in the soil seed bank and the number of indigenous species relatively few. The seed bank is overwhelmingly dominated by *Tetragonia tetragonioides* and following disturbance, germination may occur from seed in the soil or those still contained in the capsules. In general, the vegetation apart from blackwood, appears to be relatively stable.

THE ECOLOGICAL STATUS OF *ACACIA MELANOXYLON*

The blackwood scrub on Pelican Island shows great variation in vigour. Over much of the island the shrubs are in various stages of die-back and recovery and regeneration appears to be poor. A fire had burnt 60% of the island immediately preceding aerial photography in 1956. This would have rejuvenated blackwood and possibly destroyed some peat but there is no evidence of this today. Much of the scrub is in a senescent state and since regeneration appears to be only occurring by vegetative means, the dynamics and variation of the blackwood population were studied in order to ascertain the origin of the scrub and its future development.

Population structure

Methods. The size (height and basal stem girth) of each blackwood was measured in the grid of 4x1 m quadrats laid out for the floristic survey.

The health class of each shrub was assessed qualitatively as: A, healthy; B, slight die-back; C, marked die-back; and D, completely dead. Since dying stems contained numerous grass-filled borer holes, segments of wood were incubated and the adult stages of the insects identified by Catriona McPhee of Museum Victoria.

Results. Most of the blackwood scrub ranged in height from 2–4 m, and towards the periphery of the stand was reduced in height to about 1 m. On the S–SW coast dense bushes are being pruned by the onshore salt wind into a smooth profile and on the exposed NW side of the island phyllodes were also conspicuously scorched at the edge of the stand. In the centre of the island a large patch of open scrub occurs where blackwood is of low density but up to 4 m tall. The 'health score' of the population shows large patches of degenerate bushes in the SW, centre and NE of the island. The healthiest area was on the SW coast where bushes were densest, most compact and most wind sheared. The distribution of mean height and percentage cover is shown in Figs 14A and 21A. There is no evidence today of any even-aged stand structure which may have arisen following the 1956 fire, possibly as a result of a rapid turnover of stems in the last 40 years due to insect attack. No significant height differences occur in blackwood present in sites burnt and unburnt in 1956. Regeneration occurs from stem bases and root suckers. The lack of any distinct age class supports the contention that there is little, if any, accumulation of *A. melanoxylon* seed in the soil seed bank and that most regeneration is vegetative (Fig. 22).

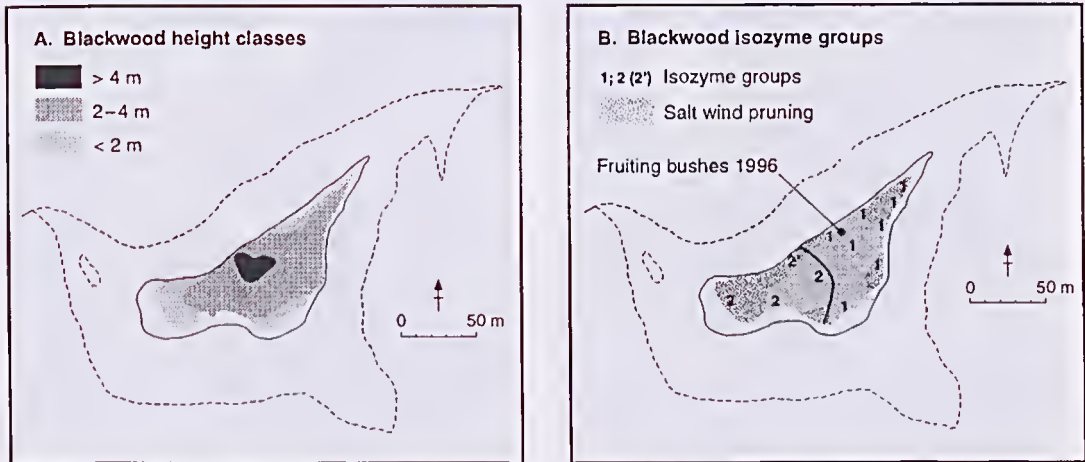


Fig. 21. A, Height distributions of *Acacia melanoxylon*. B, Map of the two main populations (A and B) and the bush (2') based on isozyme analysis, wind pruning peripheral—especially in SW.

The frequency histogram of the basal stem girths shows a normal distribution for dead and dying categories but a tendency for increasing preponderance of smaller (and probably younger) classes in the more healthy categories.

An examination of about 30 small plants 10–50 cm tall showed that all were derived from the shallow roots of nearby older bushes. No seedlings have ever been found in the field nor germinated from soil seed bank trials in the laboratory. Incubated stem samples yielded specimens of the fruit tree stem borer moth, *Maroga unipunctata* Don. Although this insect is common and probably contributes to most of the damage, larger pupal cases in blackwood stems on the island indicated that other borers were also active.

Phenology

Blackwood shrubs on the island flowered abundantly in September over the 5 years of study

from 1992 to 1995 (Fig. 23), but each year most flowers aborted after 4–6 weeks. In a few places, small green fruits 1–2 mm long developed, but within another month these too, had disappeared. This occurred not only on the exposed sides of shrubs but also in dense stands in the centre-south of the island where there was substantial protection from salt wind. In 1995 however, a few localised plants in an area measuring 10×20 m on the NW of the island produced fertile seed (Fig. 21B) from which seedlings were raised.

Phenotypic and genotypic variation

Methods. Fifteen bushes which were heavily in bud, were chosen for detailed phenological investigation at widely spaced intervals over the island. Since there seemed to be differences in phyllode size in the northern and southern area, measurements of length, width degree of curvature, taper, length of pulvinus and position of extrafloral



Fig. 22. Root sucker of *Acacia melanoxylon* beside parent shrub in the centre of the island.



Fig. 23. Flowering *Acacia melanoxylon* shoot (September 1994).

nectary were made of 20 phyllodes from each bush using the criteria of Farrell & Ashton (1978). Samples of 50 phyllodes from each of 15 bushes were subjected to isozyme analysis by Dr Gavin Moran, CSIRO, Canberra, using the methods of Muona et al. (1991) and Playford et al. (1993). Sixteen enzyme systems were assayed and 10 of these were scored for 16 isozyme loci. The heights of three bushes were measured at approximately 10 intervals down the median transect of the island. The mean values of bushes from five sites on skeletal cobble-stone soil and five on peaty soil over silty clay or silty sand were compared by Student's *t*-test.

Results. Although variation occurred in all parameters, mean values across the island did not suggest any spatial correlation that would indicate different phenotypes. In general, phyllodes were shorter and broader than those found in nearby mainland sites although there was a tendency for phyllodes to be larger in the denser shrubbery on the SW coast than in the open scrub at the NE tip of the island. The mean height of *A. melanoxylon* bushes on deeper soil with a silty subsoil was significantly greater (2.80 m) than that on skeletal soil (2.28 m) ($p < 0.05$), due possibly to greater moisture storage of the substrate. The analysis of foliar isozymes demonstrated that two major groups were present. The multilocus genotype for each bush is given in Table 4. The alleles are designated by numbers which indicate the relative rate of migration on the gel, allele 1 being the fastest allele found in studies on *A. melanoxylon*. The larger group (1) with 14 loci in common, occurred in the northeastern two-thirds of the island whilst a smaller group (2) occurred at the SW end and differed from the former in two loci (Mdh-3 and Aat-2). One bush (2') near the boundary of the two groups on the NW coast, differed from group B at two additional loci (Fig. 20B).

Discussion

The depauperate form of *A. melanoxylon* on Pelican Island represents the extreme limit of expression of this wide-ranging eastern Australian species (Farrell & Ashton 1978).

The uneven vigour of the *A. melanoxylon* bushes is a conspicuous feature of the island population. This is due largely to the chronic attack by stem-boring moth larvae. Shrubs tend to recover either by sprouting low down on the stem or by means of root suckers from shallow lateral roots. Some shrubs indicate recovery from several episodes of die-back. No seedlings have ever been observed. It is also notable that the healthiest bushes are densest in the SW where salt spray has pruned them into a smooth profile on the windward side. It is possible that this isolated community is not well buffered biologically and that insect attack of the scrub is largely unchecked. On the mainland and on the much larger French Island, stem-borer damage is insignificant. It is also possible that the stress of salt spray damage could lead to more successful insect attack. In spite of damage, root sucker vegetative regeneration has maintained the dominance of the population. The death of flowers and immature fruits is not likely to be due entirely to the presence of aerial salt since, although this would be minimal in the interior of dense scrub sites in the centre SE of the island, no retention of flowers occurred there. According to Dr Josephine Kenrick (pers. comm.) such death of flowers and young fruit is more likely to be due either to self incompatibility or to an insufficient number of the 16 cell polyad being capable of effecting fertilisation. However, in 1996, a small group of plants in the NW side in the shelter of a larger group of plants produced fertile seed with a germination rate greater than 80%. It is possible that this was an unusual event as a result of either minimal salt winds at a crucial period of seed pod development or to chance pollination from trees

Grouping Locus	Specimen number														
	1	2	3	4	5	6	7	8	9	12	11	10	13	14	15
Aat-2	11	11	11	11	11	11	11	11	11	11	12	12	12	12	12
Mdh-3	22	22	22	22	22	22	22	22	22	22	23	23	23	23	23
Ugp-2	13	13	13	13	13	13	13	13	13	13	14	13	13	13	13
Aat-3	22	22	22	22	22	22	22	22	22	22	23	22	22	22	22

Table 4. Isozyme analysis of *Acacia melanoxylon* foliage. The following loci were found in all samples: Pgm, Sdh, Mdh-1, Pgd-1, Pgd-2, Pgd-3, Gdg-1, Idh, Per-1, Per-3.

on French Island 2 km to the west or Corinella 1 km to the east. No other bushes on the island showed fertile pods in that year.

The phenological variation of the phyllode features is not great and no consistent combinations occur in any interpretable pattern. The tendency

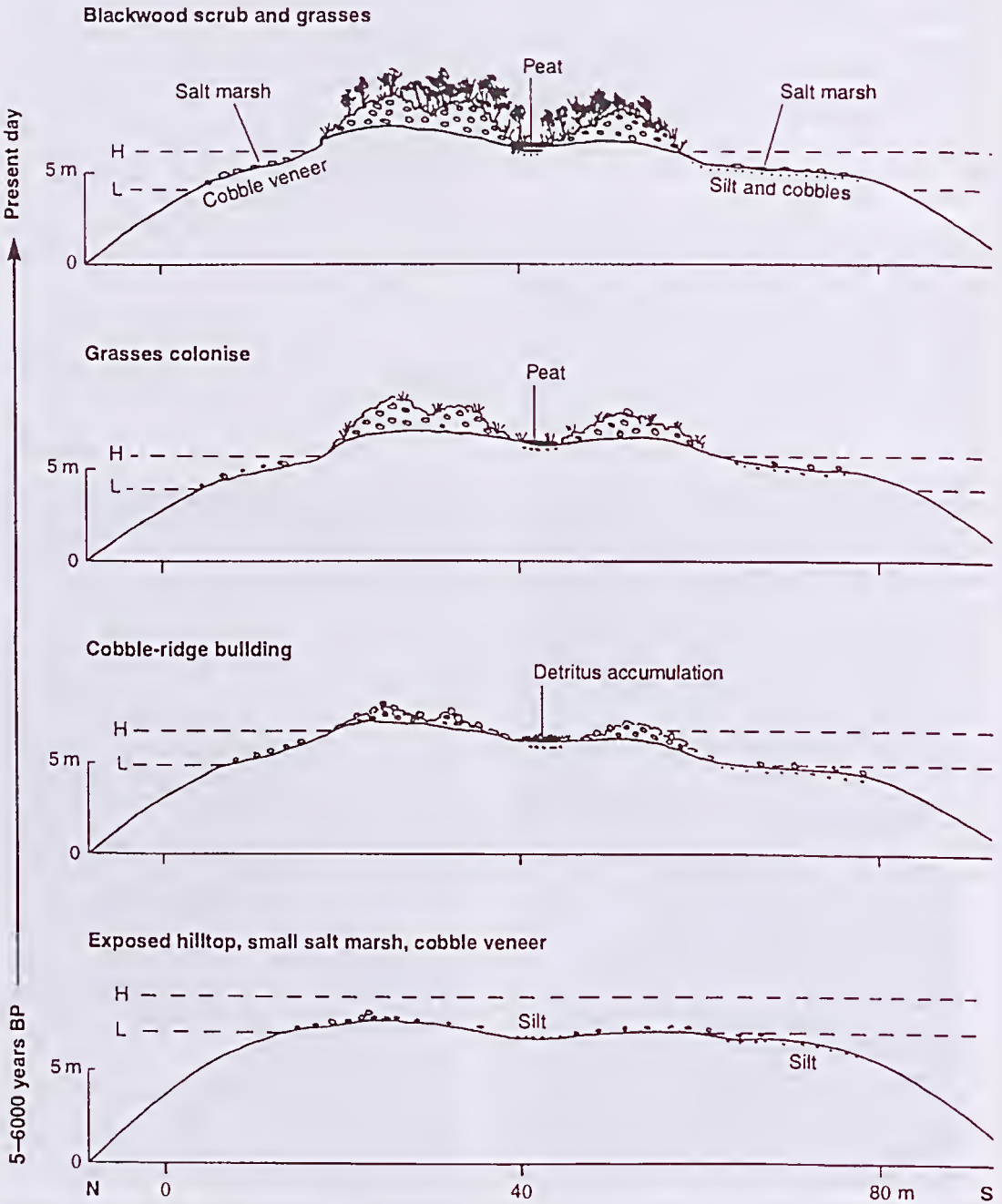


Fig. 24. Scheme of the development of vegetation on Pelican Island postulated since mid Holocene.

for smaller phyllodes to occur in the NE end of the island than the SW may be an environmental response, although the amount of salt spray damage in both sites is similar. The homogeneity of the two main isozyme groups suggest their clonal origin. It seems likely that the two groups are the result of two seeds being dispersed to different parts of the island. The single bush showing distinct differences may be a half sibling or a recent arrival. The lack of seed in the soil seed bank is likely to be due to the general lack of seed production, although clearly there may be on rare occasions, localised additions of seed to the seed bank.

The hypothesis suggested for presence and distribution of this species is that chance seed dispersal took place following the fall of sea level in mid Holocene times (5000–6000 yr BP) when the accumulation of cobble-stone ridges and the development of herbaceous swards created protected niches for seedling establishment. Blackwood appears to have persisted largely as root-suckering clones. The limited genetic variability may also contribute to the inability to resist stem-boring attack. The site is unusual for this species. On the nearby mainland coast *A. melanoxydon* is found in sheltered sites or distributed well back from the exposed coast where it reaches heights 3–4 times greater than on Pelican Island. On Bennison Island, a small granitic outcrop in the SW of Corner Inlet, *A. melanoxydon* is protected by boulders and thickets of *Melaleuca ericifolia* (Barson & Calder 1976). The occurrence of a pure stand on the exposed habitat provided by Pelican Island is therefore unusual for this species.

The future of the *A. melanoxydon* population on Pelican Island is probably precarious, since it is only slightly above high tide range, of a limited genetic resource and under persistent attack by wood-boring insects. It is possible that the initial distribution was due to bird dispersal, since the attachment of seed by a long funicle from the pod had been shown by O'Dowd & Gill (1986) to be attractive to birds. Silvereyes (*Zosterops lateralis*) may have been involved given their preference for arils and their ability to fly long distances (French 1990). The initial dispersal of *A. melanoxydon* may have been due to a chance combination of circumstances when the island became available for colonisation after a fall in relative sea level in mid Holocene times. Its subsequent continuance has probably been a result of chance events which have so far excluded more competitive woody species from nearby sites from reaching the island. It seems most unlikely that the indigenous species present today could be remnants either of the glacial phases of the

Pleistocene when sea levels were over 100 m lower than today (Gill 1961) and the whole of Western Port was dry land, or of the early Holocene when Pelican Island would have been a broad hilltop awash at high tide. The ecosystem present today appears to have developed in the last 5000–6000 years and thus encapsulates many of the historical processes operating in Western Port since that time. A scheme for such development is shown in Fig. 24.

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AIZOACEAE	<i>Disphyma crassifolium</i> <i>Tetragonia tetragonoides</i>	MYOPORACEAE	<i>Myoporum insulare</i>
APIACEAE	<i>Apium prostratum</i>	ONAGRACEAE	<i>Epilobium</i> sp.
ASTERACEAE	* <i>Aster subulatus</i> * <i>Carduus pycnocephalus</i> * <i>Conyza albida</i> * <i>Crepis capillaris</i> * <i>Hypochoeris radicata</i> * <i>Lactuca saligna</i> * <i>Leontodon taraxacoides</i> <i>Senecio laevis</i> * <i>Sonchus oleraceus</i> * <i>Sonchus asper</i> * <i>Silybum marianum</i>	OXALIDACEAE	<i>Oxalis corniculatus</i> * <i>Oxalis pes-caprae</i>
BRASSICACEAE	* <i>Cakile maritima</i> * <i>Raphanus raphanistrum</i> * <i>Sisymbrium officinale</i>	PLANTAGINACEAE	* <i>Plantago coronopus</i>
CAMPANULACEAE	<i>Wahlenbergia gracilis</i>	POLYGONACEAE	<i>Muehlenbeckia adpressa</i> <i>Rumex brownii</i> * <i>Rumex crispus</i>
CARYOPHYLLACEAE	* <i>Cerastium glomeratum</i> * <i>Polycarpon tetraphyllum</i> * <i>Silene gallica</i> * <i>Stellaria media</i>	PRIMULACEAE	* <i>Anagallis arvensis</i> <i>Samolus repens</i>
CONVOLVULACEAE	<i>Dichondra repens</i>	RANUNCULACEAE	<i>Clematis microphylla</i>
CHENOPODIACEAE	<i>Atriplex cinerea</i> <i>Atriplex paludosa</i> * <i>Atriplex prostrata</i> <i>Chenopodium glaucum</i> <i>Enchylaena tomentosa</i> <i>Hemichroa pentandra</i> <i>Sarcocornia quinqueflora</i> <i>Sclerostegia arbuscula</i> <i>Suaeda australis</i>	ROSACEAE	<i>Rubus parvifolius</i> <i>Acaena navae-zelandiae</i>
EUPHORBIACEAE	* <i>Euphorbia</i> sp.	RUBIACEAE	* <i>Galium aparine</i>
FABACEAE	* <i>Medicago polymorpha</i> * <i>Trifolium glomeratum</i>	SCROPHULARIACEAE	* <i>Verbascum virgatum</i> * <i>Veronica arvensis</i>
GENTIANACEAE	* <i>Centaurium tenuiflorum</i>	SOLANACEAE	* <i>Solanum nigrum</i>
GERANIACEAE	<i>Geranium solanderi</i> <i>Pelargonium australe</i>	VERBENACEAE	<i>Avicennia marina</i>
GOODENIACEAE	<i>Selliera radicans</i>	CYPERACEAE	<i>Isolepis nodosus</i>
LYTHRACEAE	<i>Lythrum hyssopifolium</i>	IRIDACEAE	* <i>Gladiolus</i> sp.
MALVACEAE	* <i>Lavatera arborea</i> * <i>Modiola carolinianus</i>	JUNCACEAE	<i>Juncus kraussii</i> <i>J. pallidus</i>
MIMOSACEAE	<i>Acacia melanoxylon</i>	LILIACEAE	<i>Dianella revoluta</i> var. <i>brevicaulis</i>
		POACEAE	* <i>Avena sterilis</i> spp. <i>ludoviciana</i> * <i>Briza maxima</i> * <i>Bromus diandrus</i> <i>Danthonia racemosa</i> <i>Dichelachne crinita</i> <i>Distichlis dictyophylla</i> * <i>Ehrharta longiflora</i> * <i>Halcus lanatus</i> * <i>Parapholis strigosa</i> <i>Poa labillardierei</i> <i>P. poiformis</i> <i>Puccinellia stricta</i> <i>Austrostipa stipoides</i> * <i>Thinopyrum junceiforme</i>
		ZOSTERACEAE	<i>Zostera muelleri</i>
		Total species = 80; % exotic species = 48.8	

Appendix. Vascular plant species list for Pelican Island, Western Port Bay, compiled 3 April 1993 by D. Albrecht, J. Yugovic & I. Clarke. * = exotic species.